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capacitance / conductance bridge

INSTRUCTION MANUAL

B201

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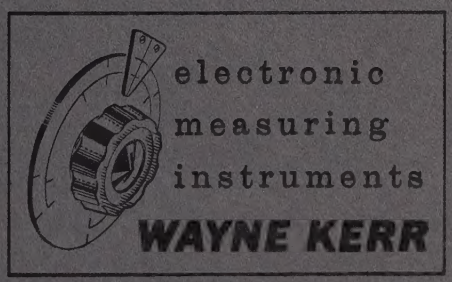

CAPACITANCE-CONDUCTANCE BRIDGE

B201

INSTRUCTION

MANUAL

THE WAYNE KERR LABORATORIES LIMITED

Sycamore Grove New Malden Surrey

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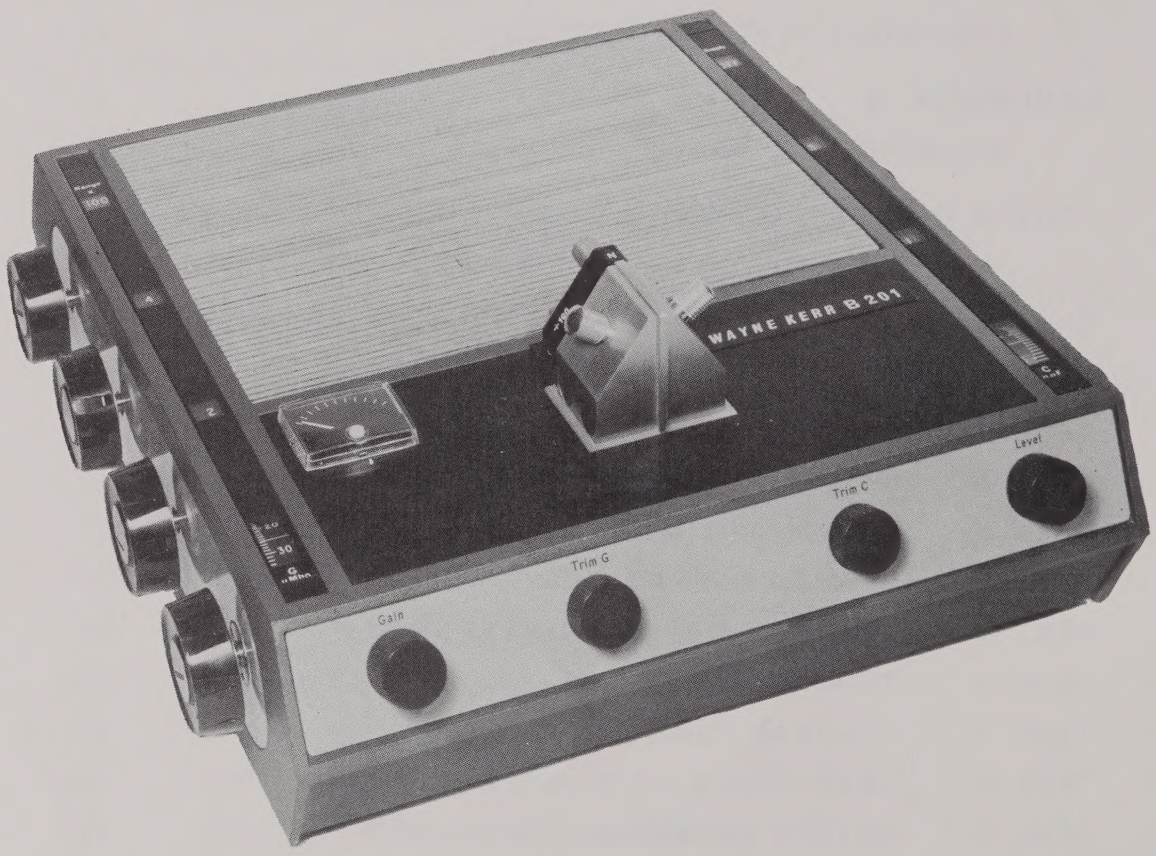

WAYNE KERR B 201
Gain
Trim G
Trim C
Level

INTRODUCTION

The B201 is a three-terminal, transformer ratio-arm admittance bridge operating at radio frequencies to provide accurate measurements of capacitance and conductance over an extremely wide range. Two displays indicate the values of the terms simultaneously.

The B201 is intended primarily for the frequency range 100 kc/s to 5 Mc/s, and is supplied with alternative fixed-frequency plug-in source and detector units so that it offers a complete measuring system. Dummy plug-in units, also provided, enable an external source and detector to be used when required.

A valuable property of the B201 is its ability to make accurate measurements even when long connecting leads are used and while the component under test remains connected in circuit. Thus remote measurements can be undertaken during tests on components and circuits that are situated in ovens, refrigerators and pressure or humidity chambers. This facility is achieved by using the 'Neutral' terminal of the bridge, which enables any arm of a delta network to be measured in the presence of the other two arms.

A common limitation in the design of bridges in the frequency range covered by the B201 is the need for variable standards throughout, which make the desirable high accuracy and clear read-out features difficult to achieve. The transformer ratio-arm principle employed in the B201 overcomes this, by enabling tapped transformers and fixed G and C standards to be used for the first two significant figures. Vernier controls are calibrated to give the third and fourth significant figures, so that a clear four-figure read-out is achieved.

Transformer ratios can be made to very high accuracies, and therefore the accuracy of the bridge depends almost entirely on the accuracy of the standards and the physical layout. High quality metal film resistors and silver mica capacitors are used as the standards and any strays present in the bridge can be balanced out for the chosen frequency before measurements are made.

A source level control enables the amplitude of the signal applied to the bridge - and hence to the point of measurement - to be adjusted, an essential facility when measuring level-sensitive parameters as in semiconductors. A gain control is also included to speed the balancing procedure when the order of measurement is not known. Balance condition is indicated visually on a Null meter, while a 1 kc/s modulation provides audible, sensitive balancing using headphones.

The B201 is constructed on the modular principle, every major circuit and all moving parts being readily accessible and easily withdrawn for maintenance. It can be operated from an a. c. power supply or from an internal 9V battery.

SPECIFICATION

Measurement Ranges §	0·0001pF - 0·1μF 0·001μMho - 1Mho (1Ω - 1000MΩ) in six ranges, including Low Admittance Adaptor LY201.
Frequency Range	100kc/s - 5Mc/s (plug-in Source and Detector units for 100kc/s and 1Mc/s).
Accuracy (100kc/s - 1Mc/s)	±0·1% ± 1 minor division ($4^{th.}$ significant figure): 1pF - 0·01μF 10μMho - 100mMho ±0·5% ± 1 minor division: 0·1pF - 1pF* and 0·01μF - 0·1μF 1μMho - 10μMho* and 100mMho - 1Mho
(1 - 3Mc/s)	As above, multiplied by (frequency in Mc/s)^2
Discrimination	± 1 minor division or better
Dimensions	Bridge 13 1/2 x 12 1/2 x 5 1/4 in. (34 x 32 x 13 cm.) 12 lb. (5·5kg) Wooden case 17 3/4 x 15 3/4 x 5 7/8 in. (45 x 40 x 15 cm.) 14 lb. (6·4kg)
Total Weight	27 lb. (12·3kg). This is Bridge, Case, 100kc/s and 1Mc/s Sources and Detectors, and Dummy plug-in units for external Source and Detector.

* Coverage provided by Low Admittance Adaptor LY201

§ See table on page 28

OPERATING PRINCIPLES

THE BRIDGE

The B201 is based on a transformer ratio arm bridge circuit, the theory and operation of which is discussed fully in Wayne Kerr Monograph No. 1 (available on request).

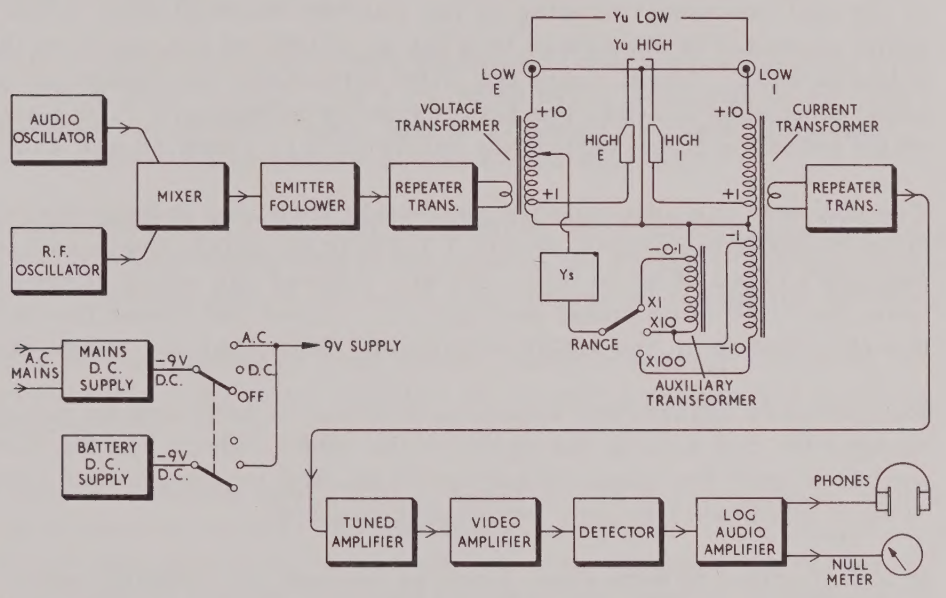


FIG. 1 FUNCTIONAL DIAGRAM OF B201

The bridge circuit is shown schematically in the block diagram of Fig. 1. The unknown admittance Y_u is connected to the HIGH or LOW terminals, depending on its estimated value, and adjustments are made to the bridge until the magnetic fluxes set up in the two halves of the current transformer are equal and in antiphase. Two adjustments are available for balancing the bridge. First, different voltages can be applied to the unknown and standard (Y_s) admittances, and second the currents passed by the admittances can be fed through a different number of turns on the respective halves of the current transformer.

Variation in the relative potential applied to Y_s is achieved by providing the source voltage transformer with ten equal taps, so that Y_s can be switched through the range. With Y_u connected to the HIGH terminals (supplied from the +1 tap), the voltage applied to Y_s can be adjusted to be from one to ten times greater than that applied to Y_u. Similarly, with Y_u connected to the LOW terminals, the voltage applied to Y_s

can be adjusted from one to one-tenth of that applied to Y_u.

The current transformer is tapped to provide different turns ratios between the two halves of the winding. Additionally, an auxiliary transformer can be switched into circuit on the 'standard' side of the current transformer, between the 1-turn tap and the neutral line. The auxiliary transformer is also tapped at 1/10th of its total turns - representing 1/100th of the turns on the 'standard' side of the current transformer. The LOW terminal is connected to the full 'unknown' winding of the current transformer, while the HIGH terminal is connected to a tap at 1/10th of the turns on the unknown side. Thus, from the LOW terminals, the ratios of transformer turns available between the two current windings are 1, 0·1 and 0·01, while from the HIGH terminals ratios of 0·1, 1 and 10 are available.

Coupled with the adjustments obtainable from the voltage transformer (1 to 10 HIGH terminals, 0·1 to 1 LOW terminals), these ratios provide ranges of up to 0·01, 0·1 and 1 times the value of the standard from the LOW terminals, and up to 1, 10 and 100 times the value of the standard from the HIGH terminals. Note that one range is duplicated.

Four-decade adjustment within each range is achieved by providing two standards, one a tenth the value of the other, which can be independently switched over the range of voltage taps, and by providing a vernier control calibrated to give two-figure readout.

It is important to note that, since at balance no potential exists across the current transformer, it is possible to connect an impedance between the current side of the LOW or HIGH terminals and the neutral line without affecting the accuracy of the measurement. A reduction in sensitivity would result, but this can be compensated by increasing the gain of the detector circuits.

Similarly, an impedance can be connected between the voltage side of the LOW or HIGH terminals and the neutral line. This would reduce the voltage applied to Y_u, but would reduce also the voltage applied to Y_s in proportion to the turns ratio. With the relative voltages remaining unchanged the accuracy is unaffected, and the reduction in sensitivity can be compensated, as before, by increasing the detector gain.

Hence, in most instances, components can be tested in situ.

Transformers can be manufactured and the taps set with considerable precision, and therefore the accuracy of the bridge depends almost entirely on the standards and the circuit layout. High quality metal film resistors and silver mica capacitors are used as the standards and, since these are of fixed value, they can be set during manufacturer's tests to give greater accuracies than could be achieved by using variable standards.

The effect of stray capacitances and inductances within the bridge circuit varies with the frequency used, and TRIM controls are provided to balance out such strays before measurements are made. The entire circuit has been carefully designed to keep lead lengths to an absolute minimum, and correction networks have been included to minimize even small sources of error, to provide an exceptionally high degree of measuring accuracy.

SIGNAL SOURCE CIRCUITS

Both r.f. oscillator and mixer sections of the source circuits are built into a plug-in unit, two such units being available to provide frequencies of 100 kc/s and 1 Mc/s, although any spot frequency between 100 kc/s and 5 Mc/s can be accommodated.

The oscillator is of the tuned LC variety, a ferrite core in the inductor and silver mica capacitors being used in the tuning to permit accurate frequency setting and to ensure a high degree of frequency stability.

A Wien bridge circuit is used for the audio oscillator, tuned to approximately 1 kc/s and adjusted to provide a modulation depth of nominally 80%.

The mixer is driven into Class C operation by the oscillator, and has a high-Q load to recover the sinusoidal waveform. A 'dummy' plug-in unit is also provided, to permit use of an external modulated oscillator source: when this unit is used, the input is routed direct to the repeater transformer via the SET LEVEL control.

The mixer output is applied to a wide band emitter follower which, in conjunction with a repeater transformer, matches the high impedance mixer load and the low impedance bridge input.

The output of the emitter follower is coupled to a repeater transformer via the SET LEVEL control, which enables the level of the signal applied to the bridge - and therefore to the point of measurement - to be varied, an important facility when measuring components such as semiconductors which have level-sensitive parameters.

Apart from their matching functions, the repeater transformers provide a high degree of isolation, virtually eliminating frequency pulling of the oscillator.

DETECTOR CIRCUITS

The bridge output is applied, via a repeater transformer and the GAIN control, to a two-stage tuned amplifier constructed as a plug-in module.

The tuned amplifier is followed by a wide-band common-base transistor stage, which feeds a two-stage video amplifier. The signal is then detected in a conventional diode circuit, and part of the d. c. component is fed back to the tuned amplifier via a diode network which provides 'delayed' a. g. c. This technique preserves the gain around the null point where maximum sensitivity is required, and gives maximum a. g. c. at high signal levels where a reduction in gain is desirable.

The detected signal is amplified in a direct-coupled circuit which incorporates a level-sensitive feedback loop to provide a logarithmic amplitude response. The audio signal is applied to a 'phone jack, and is rectified in a conventional bridge circuit to provide d. c. for the null balance meter.

Power for the circuit is derived from a 9V battery or from a stabilized transistor circuit operating from a. c. supplies. Both battery and power unit are embodied within the B201.

OPERATING INSTRUCTIONS

POWER SUPPLIES

The B201 will operate from a 9V battery (PP6 or equivalent) or an a. c. supply of 110V to 115V or 200V to 250V, 50 to 60c/s.

The battery fits into a special compartment in the base of the instrument, access to the compartment being gained by removing the small protective cover.

For a. c. operation, check first that the voltage indicated on the label is correct for the local supply. If adjustment is necessary:

Remove the base plate of the B201

Remove the power unit printed circuit panel (see Fig. 9) by releasing the securing screws and withdrawing the plug.

For 110V to 115V supplies, link transformer terminals 1 to 2, and 3 to 4.

For 200V to 250V supplies, link 2 to 3 only.

Check that the fuse FS1 is of the correct rating (150mA for all voltages).

CONTROLS

Refer to the plate at the base of the instrument for location and designation of the controls. The function of each control is as follows:

Supply Switch: A three position switch permitting selection of 'off', the internal d. c. or external a. c. power supply.

Set Level: A variable control enabling the amplitude of the signal applied to the bridge (and hence to the measuring point) to be adjusted. The control is in circuit for both internal and external sources.

Gain: A variable control enabling the amplitude of the signal applied to the detector circuits to be adjusted: generally the gain is increased as the null point is approached.

Trim G, Trim C: Two controls which, together, enable any strays in the bridge to be balanced out before measurements are made. Since strays tend to be frequency dependent, the bridge will require re-trimming if the frequency is changed.

Decade and Vernier: One Vernier and two Decade controls are provided for capacitance and for conductance balancing.

The 'G' or conductance dials read in micro-Mhos, and provide a four-figure read-out (the Vernier is scaled 00 to 100 to provide a direct two-figure read-out). The reading is directly amended by the Range multiplier and, when the LOW terminals are being used, by a further factor of 1/100. Thus, from the HIGH terminals:

$$G = (\text{the four-figure read-out} \times \text{range multiplier})\mu\text{Mhos}$$

and from the LOW terminals:

$$G = \frac{\text{the four-figure read-out} \times \text{range multiplier}}{100}\ \mu\text{Mhos}$$

The 'C' or capacitance dials read in pico-Farads, and provide a read-out of three whole figures and one decimal place (the Vernier is scaled 0 to 10 with subdivisions for the decimal place). The reading is directly amended by the Range multiplier and, when the LOW terminals are being used, by a further factor of 1/100. Thus, from the HIGH terminals:

$$C = (\text{the three whole, one decimal read-out} \times \text{range multiplier})\text{pF}$$

and from the LOW terminals:

$$C = \frac{\text{the three whole, one decimal read-out} \times \text{range multiplier}}{100}\ \text{pF}$$

Note: The decade and vernier controls are scaled 0 to 10 (00 to 100 in the case of the G vernier), so that a read-out of, say, 1000 can be achieved either by setting the first decade to '1' and the second decade and vernier to '0', or by setting

the second decade to '10' with the other two at '0'. This arrangement provides a useful overlap between decades. A further overlap is provided by making the highest LOW terminal range a duplication of the lowest HIGH terminal range.

OPERATING PROCEDURE

Source and Detector: Where an external source and detector is to be used, fit the 'S EXTERNAL' plug-in unit to the left rear compartment (as viewed from the rear) and the 'R EXTERNAL' plug-in unit to the right compartment. The external source and detector circuits are then connected to the BNC sockets on the 'S' and 'R' plug-in units respectively. The source should provide approximately 3V rms into 30Ω at 100kc/s, 10V rms into 300Ω at 1Mc/s. Wayne Kerr Video Oscillator 022D (covering 10kc/s to 10Mc/s) is an ideal external source. The detector should be tuned and have a sensitivity of 1μV. Communications receivers covering the desired frequency range are suitable.

For 'internal' operation, select the S201 and R201 plug-in units - both of the same frequency - and fit into the left and right compartments respectively, as viewed from the rear.

Initial Trimming: Switch the Range multiplier to the 'x 1' position and all decade and vernier controls to zero. Remove any components from the terminals or leads. Set the Gain control to maximum, and adjust the Trim C and Trim G controls to balance the bridge, using the null meter and headphones for maximum sensitivity. The initial trim will suffice for all ranges within ±1 minor vernier division, although further trimming can be undertaken on each range if desired.

It is necessary to re-trim if the frequency of operation is changed.

Measurement of G and C: If it is possible to identify the nominal value of the unknown component, the appropriate range can be selected, and the component connected to the HIGH or LOW terminals accordingly. Where small values of capacitance are to be measured, or small values of conductance, the LOW connectors are used, in association with the Low Capacitance Leads supplied. High values of admittance should be measured using the HIGH terminals. The 'penthouse' shape of the terminal block is designed for minimum fringe field and to eliminate disturbance when a component is connected. It also ensures that low-inductance connections can be made between the Bridge and the Unknown.

Where the nominal value is not known, connect the component to the HIGH terminals and set the Range multiplier to the 'x 100' position. Increase the Set Level and Gain controls from their minimum positions until the null meter registers about half full scale deflection.

Adjust both G and C controls for a minimum reading on the meter, increasing the Set Level and Gain controls progressively until the final balance is reached.

If less than a four-significant-figure read-out is achieved at balance for the major term, select the appropriate range and repeat the null balance procedure. For maximum accuracy, the first significant figure of the major term should be registered on the first (highest) decade control.

For maximum discrimination, the headphones should be used in addition to the null meter.

Note that the bridge measures the unknown as parallel connected quadrature components.

Refer to the procedure in the next paragraphs should one component of the unknown appear to be negative.

Measurement of -G and -C: Although the B201 is designed to measure +G and +C, it can easily be adapted to measure negative values: a small amount of -G and -C is provided on the vernier controls, the scale for these negative values being in red.

Suitable values of G and C can be connected to the bridge to 'bias back' the decade and vernier controls to a full scale deflection or any intermediate point. The bridge is then trimmed to this reading before the negative unknown is connected.

Balancing proceeds as before, and the value of the unknown is the reading for balance subtracted from the initial off-set value. Thus:

$$G = -(G \text{ off-set value} - G \text{ measured value})$$

$$C = -(C \text{ off-set value} - G \text{ measured value})$$

The procedure may be necessary to balance either the major or the minor term of the unknown.

LIMITATION OF THE HIGHEST RANGE (x100, HIGH terminals)

While this range is capable of an accuracy of 0·5%, the presence of some resistance in the connections to the unknown terminals and the transformer resistance modifies the value of 'G' to be measured.

A correction may be applied, knowing that the effective series resistance, looking back into the HIGH terminals, is

$$Rs = 7{\cdot}5 \text{ milliohms}$$

Note: An accuracy of 1% can be assumed without any corrections.

For reference, details on Series-Parallel conversion are given in a following paragraph.

When measuring C on this range, care must be taken to avoid inductive loops in the capacitor connections, since a series inductance of 0·025μH will affect a 0·1μF capacitor by some 0·1% at 100kc/s.

This range may prove more useful in detecting frequency errors in components than in the measurement of their precise values, since it will be difficult to establish pure components.

PARALLEL TO SERIES CONVERSION

Impedance is defined by Ohm's Law as $Z = E/I$, the ratio of a voltage to a current. If the impedance is complex, the voltage-to-current ratio must also be complex and E or I must have two components. If the voltage is chosen as the reference, the current must have the form $I_r \pm jI_x$, where I_r is in phase with E and I_x is in quadrature. If the current is chosen as a reference, the voltage must have the form $E_r \pm jE_x$, where E is in phase with I and E_x is in quadrature. There are, therefore, two distinct but equivalent ways of representing a given complex impedance.

As stated earlier, the bridge measures the Unknown in terms of the <u>parallel</u> components of conductance and capacitance. If the constants of the unknown are required in terms of equivalent series components, they can be calculated from the relationships:

$$R_s = 1/[G(1 + Q^2)]$$

$$C_s = C[1 + (1/Q^2)]$$

$$L_s = -1/[\omega^2 C(1 + 1/Q^2)] \qquad [Q = 2\pi fC/G]$$

$$X_s = X/[1 + (1/Q^2)]$$

where G and C are the values of the parallel components obtained from the bridge main dials.

If $Q \gg 1$:

$$R_s \simeq 1/Q^2G \qquad C_s \simeq C \qquad L_s \simeq 1/(\omega^2 C) \qquad X_s \simeq X$$

If $Q \ll 1$:

$$R_s \simeq 1/G \qquad C_s \simeq C/Q^2 \qquad L_s \simeq Q^2/(\omega^2 C) \qquad X_s \simeq Q^2X$$

TECHNICAL DESCRIPTION

GENERAL CONSTRUCTION

The bridge is constructed on a strong, tray-shaped chassis of cast alloy, with the circuit components mounted underneath and protected by a base plate. A removable panel in the base plate allows access to the battery supply. All the controls necessary for operation are arranged around the edge of the unit, the plug-in oscillator and tuned amplifier units fitting into recesses at the rear. The disposition of the controls and major components is shown in the layout diagram, Fig. 9.

The methods used for switching the conductance and capacitance standards across the transformer taps, and for range switching, have been carefully designed to keep lead lengths to a minimum. Each switch system operates in a similar manner: the arrangement for one is illustrated in Fig. 2.

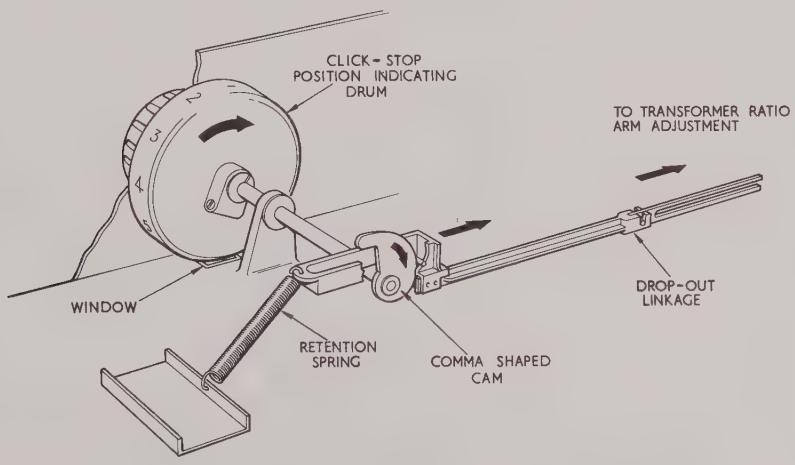


FIG. 2 SWITCH LINKAGE SYSTEM

The control knob is fitted onto a spindle which is supported through the chassis side and a bracket. A click-stop numeral drum is fitted on the spindle inside and adjacent to the chassis side, so that the numeral corresponding to the decade value of the selected transformer tap appears in a chassis cut-out or window at the top of the bridge. At the extreme end of the spindle, a 'comma shaped' cam bears on a spring loaded push-rod, the end of which carries the moving contact for the transformer taps. Thus when the switch is rotated, the cam pushes the rod - or allows it to return under spring tension - to perform the desired switching operation. The entire system uses drop-out linkages, for ease of removal and maintenance.

Each circuit of the B201 is contructed on an easily removable module or printed circuit panel, with interconnections made by plugs and

sockets. Thus access can readily be gained to any part of the circuit with minimum disruption of components. The standard components and the current and voltage transformers are mounted in a vertical 'stack' beneath the terminal block to which the test component is fitted, so minimizing 'strays'. This entire nucleus can also be removed quickly and easily, should it ever be necessary for servicing or fault finding.

The Bridge is supplied in a polished wood case with fitted compartments housing all leads, the 'phones, alternative frequency source and detector units, the 'dummy' units for external source/detector and spare terminals. Space is provided also for the Low Admittance Adaptor, Transfer Standards and a spare battery.

POWER SUPPLIES

The B201 can be operated from an internal 9V battery (type PP6), or from a single-phase a. c. supply of 110V or 220V. Fig. 3 shows the supply switching arrangement and the circuit for the internal power unit.

The supply selector control knob is located on the right side of the unit, indication of the selected position - OFF, D. C. or A. C. - appearing in the window alongside the knob. In the D. C. position, contacts on the two-pole three-position switch connect the 9V battery supply to the bridge circuits, while in the A. C. position the stabilized output of the power unit is selected. A toggle switch, mechanically linked to the spindle of the wafer switch, completes the a. c. supply to the input of the power unit transformer via the 150mA fuse FS1.

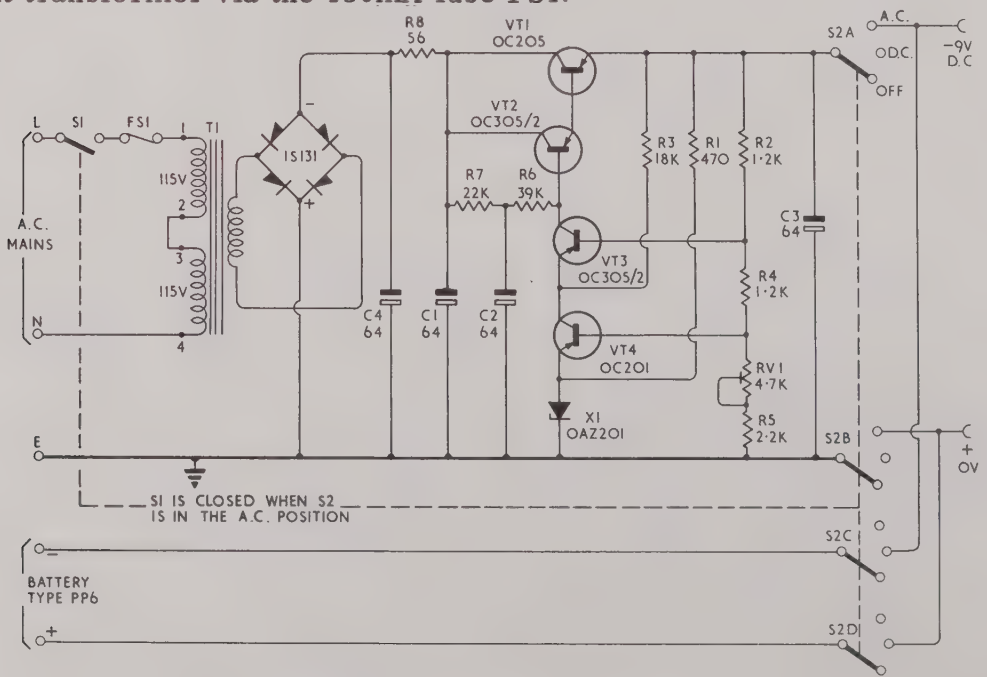


FIG. 3 POWER UNIT AND SWITCHING ARRANGEMENT

The secondary output of T1 is rectified by a full wave bridge circuit and smoothed by capacitive input filter C4, R8, C1. Transistors VT1 to VT4 are connected in a circuit which stabilizes the -9V output of the unit. VT4 emitter is held at a reference potential of 5·1V by Zener diode X1, while the base is supplied from the potentiometer network R2, R4, RV1 and R5, connected across the output.

Any variation in the output produces a corresponding change at the base of VT4, which is amplified by VT4 and VT3 and applied, via emitter follower VT2, to the base of VT1. This transistor operates as a series regulator: the change in its base bias affects its impedance and, hence, minimizes the variation of output voltage. RV1 sets the mean operating point of VT4 base, and hence the level of the output voltage.

R. F. OSCILLATOR

Transistor VT1 is connected in a conventional L. C. tuned r. f. oscillator circuit (Fig. 4), the frequency being determined by the value of components C1, T1 and C4.

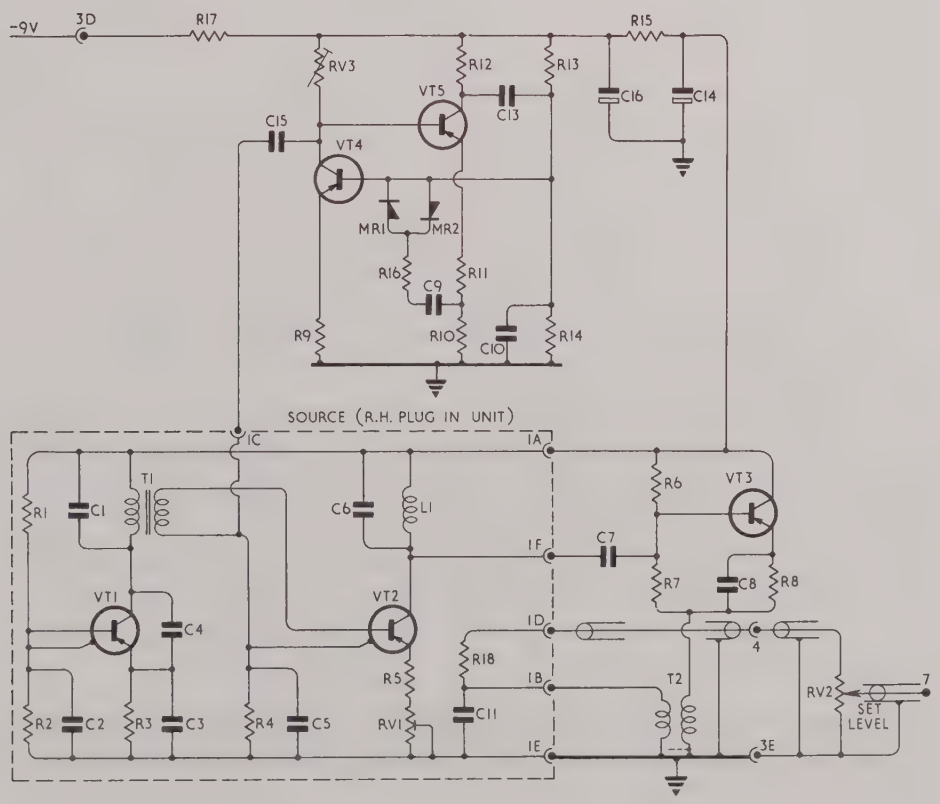


FIG. 4 OSCILLATORS AND MIXER

The phase of the feedback to VT1 emitter is controlled by C3, the value of which depends on the particular frequency of the oscillator. R1 and R2 provide base bias for VT1, with decoupling by C2. The screen of VT1 is connected to ground - as far as r.f. is concerned - by C2. The oscillator output is directly coupled to the base of the mixer transistor VT2 from the secondary of T1.

AUDIO OSCILLATOR

Transistors VT4 and VT5 are connected in a Wien bridge oscillator circuit, the frequency - approximately 1kc/s - being determined by R12, C13, R14 and C10. Resistor R14 serves also to establish the d.c. bias.

A diode circuit, MR1 and MR2, is used in place of the amplitude-controlling thermistor generally found in Wien bridge oscillators, to provide a non-linear negative feedback loop. This broadens the oscillator's setting range - which could otherwise be fairly critical - and reduces changes in frequency due to reducing battery voltage. When the circuit is initially switched on, the voltage across the diodes is low so that they are not conducting, and the 'start' conditions are not affected. As oscillations build up, the diodes conduct, reducing the forward loop gain so that the circuit limits before distortion occurs.

Pre-set resistor RV3 provides adjustment to give oscillating conditions with minimum distortion and, since its effective range of control is extended by the diode feedback loop, it also enables the modulation depth to be set.

MIXER AND R.F. OUTPUT

The audio oscillator output is developed across R4 and C5, which presents a short circuit to r.f. Thus mixing of r.f. and audio signals occurs at the base of VT2 which, since there is no base bias, is driven into Class C operation.

C6 and L1 form a high Q collector load, tuned to the r.f. oscillator frequency with adequate bandwidth for the modulation sidebands.

Variable resistor RV1 in the emitter load of VT2 enables the r.f. output level to be adjusted, and is pre-set to half the full output possible: thus 100% modulation could be achieved, if required, without overloading the circuit.

The modulated signal is applied via C7 to the base of the wideband emitter follower VT3, bias for which is provided by R6, R7 and R8.

VT3 circuit matches the high impedance mixer circuit to the low impedance bridge input, the emitter load being the bridge impedance as reflected in transformer T2.

For the 100kc/s r.f. oscillator circuit, components R18 and C11 are included in circuit, while for the 1Mc/s circuit, socket terminals 1D and 1B (in the plug in unit) are linked together. At 100kc/s the bridge input impedance is lower and inductive and, if not corrected, would overload the emitter follower and cause distortion. R18, between T2 secondary and the bridge, and C2 - which broadly tunes T2 to 100kc/s - recover the desired impedance and so restore the performance of the circuit.

The SET LEVEL control RV2, connected between the emitter follower and bridge circuits, enables the amplitude of the r.f. signal to be adjusted to a maximum of 2V peak-to-peak.

The -9V supply for the r.f. oscillator, mixer and emitter follower circuits is decoupled by R15, C14 and C16.

TRANSFORMER RATIO ARM BRIDGE

The operation of the bridge circuit, shown in Fig. 5, is described briefly in the operating principles section of this book, a more detailed description being given with the theory in Wayne Kerr Monograph No. 1.

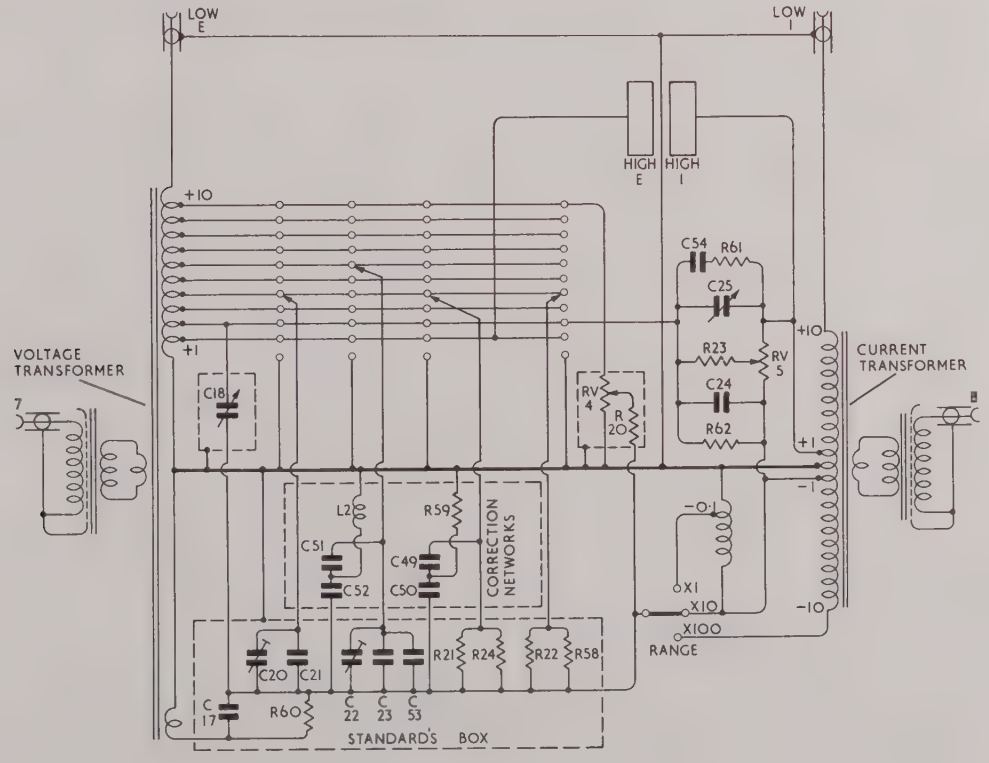


FIG. 5 TRANSFORMER RATIO ARM BRIDGE

The capacitance standards are formed by C23 (first decade), C21 (second decade) and C18 (vernier). Pre-set capacitors C22/C53 and C20 enable C23 and C21 respectively to be set to the precise values. C17 is supplied from a 'bucking' winding on the voltage transformer to 'back off' the residual capacitance of the vernier control and so provide it with a proper zero setting.

The conductance standards are provided by R21 (first decade), R22 (second decade) and R20/RV4 (vernier). R24 and R58 are selected during manufacturer's tests to set precisely the values of R21 and R22. 'Backing off' provided by R60 gives the G vernier a true zero and some negative G.

Correction networks (C49-C52, L2 and R59) operate on the G and C standards, respectively, to give the desired overall frequency response.

Variable capacitor C25 and potentiometer RV5 enable any unbalance in the circuit caused through 'strays' to be balanced out before a measurement is made, and they form the TRIM C and TRIM G controls respectively.

TUNED AMPLIFIER

The bridge output is applied to the emitter of VT7 (Fig. 6) via a repeater transformer and the GAIN control RV6: the emitter input matches the bridge impedance of approximately 75 ohms.

VT7 and VT6 are connected in a two-stage tuned amplifier circuit with 'delayed' a. g. c. feedback applied via diodes MR5 to MR8 to improve the dynamic range of the detector circuits.

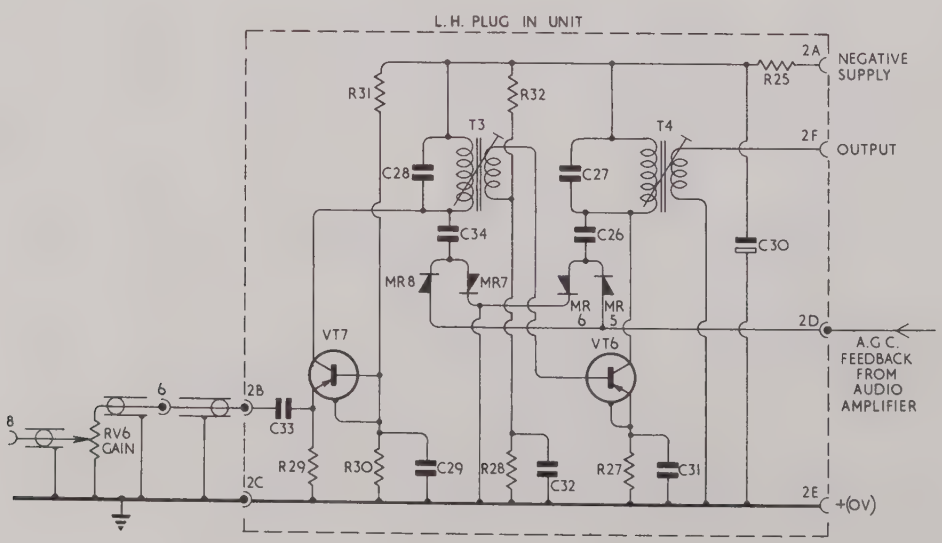


FIG. 6 TUNED AMPLIFIER

The d. c. signal derived from the detector circuit is applied via MR8 and MR5 to control the operating points of MR7 and MR6, which shunt the tuned collector circuits of VT7 and VT6. For low d. c. signals - that is, around the null or balance condition of the bridge - MR8 and MR5 present a high impedance, and the amount of a. g. c. applied is small. For higher d. c. signals MR8 and MR5 have a low impedance, so that the operating point of MR6 and MR7 is reduced and a larger proportion of the r. f. signal is shunted to earth. The gain of the circuit is thus preserved around the null point, and maximum a. g. c. is applied for large out-of-balance signals.

The tuned amplifier is constructed as a plug-in unit, components C28, T3, C27 and T4 being selected to provide a frequency corresponding to the source plug-in unit.

VIDEO AMPLIFIER

The tuned amplifier output is coupled to the emitter of VT8 via C35 (Fig. 7). VT8 is connected in a wide band common base amplifier stage which matches the 75 ohm impedance of the tuned amplifier to the following video amplifier stages, to present a constant current source.

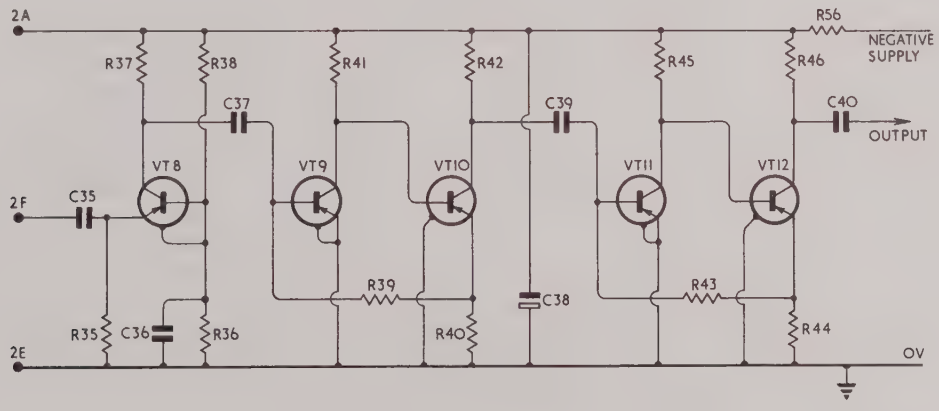


FIG.7 VIDEO AMPLIFIER

VT9/10 and VT11/12 are connected as current amplifier pairs with the gain controlled in each by negative feedback (via R39 and R43). The two transistors forming a pair are direct coupled and d. c. stabilized, and are virtually independent of frequency-conscious parameters. Capacitive coupling (C39) is used between the two stages, and the high impedance load of the first pair (R42) ensures that the second pair - with an input impedance less than 20 ohms - is driven from a constant current source.

The overall circuit VT8 to VT12 is designed to give a response within 2dB over the range 100kc/s to 5Mc/s, and a gain of 60dB.

DETECTOR AND AUDIO AMPLIFIER

The video amplifier output is detected by MR9 (Fig. 8), part of the signal being fed back to the tuned amplifier as a. g. c. via MR16.

Audio amplification is provided by direct coupled transistors VT13 and VT14, with level sensitive feedback via MR10 and MR11 to give a logarithmic amplitude response. The audio output, developed across emitter load R55 and R54, is applied to the headphone jack via C47/C55, and is rectified by bridge network MR12 to MR15 for application as a d. c. signal to the null balance meter M1.

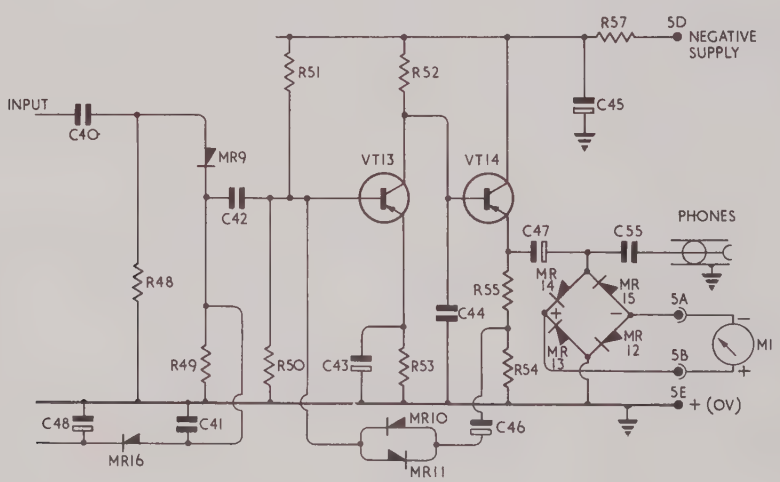


FIG. 8 DETECTOR AND AUDIO AMPLIFIER

SERVICING INFORMATION

REMOVAL OF UNITS

With the exception of the bridge nucleus, each of the major circuit units can easily be withdrawn by simply removing the appropriate securing screws and releasing the plug connections (see Fig. 9).

To remove the bridge nucleus it is necessary to carefully unsolder the leads extending to the components on the top assembly, revealed when the top cover is removed.

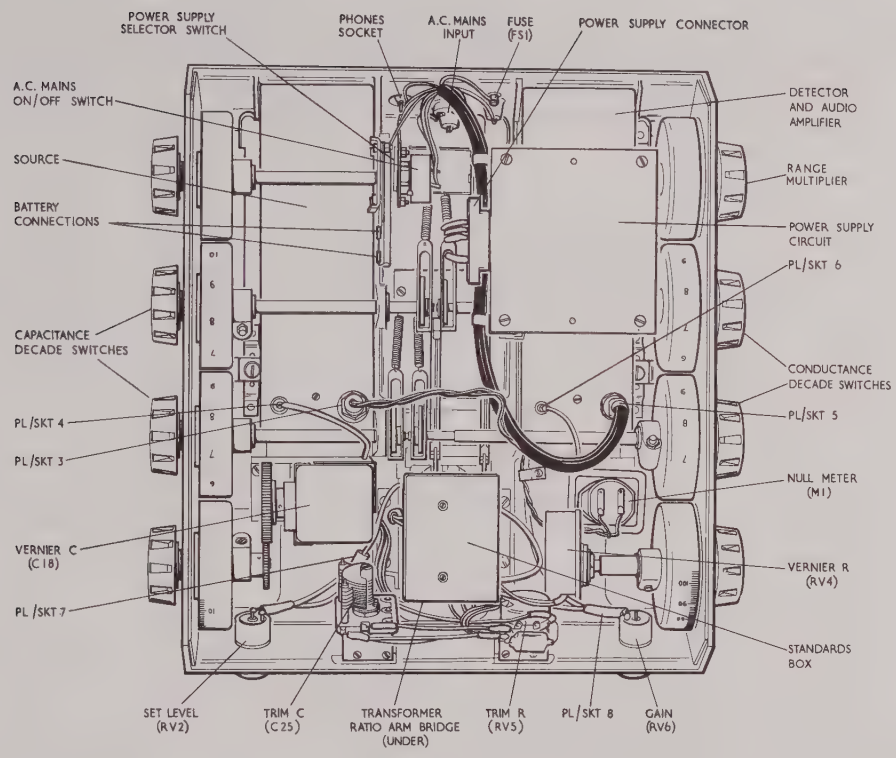


FIG. 9 LAYOUT OF MAJOR COMPONENTS

PERFORMANCE TESTS

The following tests are given to assist users when the bridge performance is suspect: they are not intended to form or be part of a maintenance routine. The tests should only be undertaken by a competent engineer.

Oscillators

Withdraw SK1 and switch on the B201. Using a suitable oscilloscope, check that the sinusoidal waveform appearing on pin C of the 'fixed unit' (PL1) has an amplitude of approximately 2·5V. RV3 can be adjusted, if necessary, to provide a maximum sinusoidal output with minimum distortion: the final setting of RV3 should be such that the modulation depth (checked at the mixer output) is 80%. The audio oscillator frequency should be approximately 1kc/s.

Replace SK1. With the oscillator connected to the mixer output - i. e. C7 - the peak-to-peak voltage should be 1·2V. RV1 provides any necessary adjustment, which is best achieved with the audio oscillator 'off' by temporary adjustment of RV3.

The frequency of the plug-in module can be checked, and the core of T1 adjusted if the frequency differs from that stated on the module. Should adjustment be necessary, it will be found easier to withdraw the unit and to connect a separate -9V supply to it, in accordance with the circuit diagram details.

Accuracy Check

The accuracy of the bridge can be checked using Transfer Standards (detailed below) and comparing the performance with a Wayne Kerr B221A Bridge. Transfer Standards Q201, checked to ±0·02% at 1kc/s, are 1000pF, 100pF and 10pF, 100 ohms (0·01 Mho), 1kΩ (1000μMho) and 10kΩ (100μMho).

Check as follows:

B201 Range		Standard	Tolerance (±)
x1	HIGH	1000pF	1pF
x10	HIGH	1000pF	2pF
x10	LOW	100pF	0·1pF
x100	LOW	100pF	0·5pF
x100	LOW	1000pF	5pF
x10	LOW	10pF	0·02pF
x1	LOW	10pF	0·01pF
x1	HIGH	0·01Mho	10μMho
x10	HIGH	0·01Mho	20μMho
x10	LOW	1000μMho	1μMho
x100	LOW	1000μMho	2μMho
x100	LOW	0·01Mho	50μMho
x10	LOW	100μMho	0·2μMho
x1	LOW	100μMho	0·1μMho

Check and Adjustment of C Standards

The values of the Standards can be checked and, if necessary, adjusted by the following procedure. The equipment required, apart from the Transfer Standards as detailed above for 'Accuracy Checks', is

An oscillator covering 700kc/s (e.g. Wayne Kerr 022D)
Valve Voltmeter (e.g. Wayne Kerr M121)
Detector covering 700kc/s, sensitivity 1μV

With the external source and detector connected and set to 700kc/s, trim the bridge on the x1 range, with all dials set to zero. Connect the 1000pF Transfer Standard (adjusted to 1000pF ±0·02% at 1kc/s) to the HIGH terminals. Set the main decade 'C' dial to '10', and adjust C22 for null on the detector. Set the main decade 'C' dial to '9' and the second decade 'C' dial to '10', and adjust C20 for null.

Set the second decade 'C' dial to '9' and the Vernier 'C' to '10'. Null should occur within ±1 minor division of the '10' on the Vernier 'C'. If necessary the outer plates of the Vernier 'C' can be adjusted.

Check and Adjustment of G Standards

The equipment and procedure detailed in the preceding paragraph can be adopted, using a 100 ohm (0·01Mho) Standard adjusted to ±0·02% at 1kc/s, and the G decade and Vernier controls. The value of the shunts required to trim the G standards are

$$\text{Shunt R} = \frac{1000}{\text{G dial error in } \mu\text{Mho}} \text{ k}\Omega$$

For example, if the G dials read 10095μMho, then

$$\text{Shunt R} = \frac{1000}{95} \text{ k}\Omega = 10{\cdot}5\,\text{k}\Omega$$

Range Correlation Check

Using the 100 ohm and 100pF Transfer Standards, check that the x10 range with '1' on the first, main, decade corresponds to the x1 range with '10' on the first decade, and to within ±2 minor divisions on the x10 range.

TYPICAL VOLTAGES

The values quoted in the following paragraphs are typical for a Bridge in normal working order.

D. C. Voltages Relative to Ground (20 000 ohm/volt meter)

Transistor	Emitter	Base	Collector
VT1	0·6	0·8	8·6
VT2	0·25	-	8·6
VT3	0·57	0·8	8·6
VT4	0·95	1·07	3·0
VT5	3·0	3·1	6·5
VT6	1·6	1·78	7·5
VT7	1·6	1·78	7·5
VT8	0·7	0·78	4·0
VT9	-	0·28	0·58
VT10	0·3	0·58	4·2
VT11	-	0·28	0·58
VT12	0·3	0·58	4·2
VT13	0·8	0·9	3·5
VT14	3·5	3·6	8·1

Signal Voltages Relative to Ground (Peak-to-peak, measured on an oscilloscope)

a) Source

Transistor	Emitter	Base	Collector	Frequency
VT1	0·15	-	-	1Mc/s
VT2	1·2	-	-	1Mc/s modulated
VT3	8·5	1·0	-	1Mc/s modulated
VT4	-	0·55	2·5	1kc/s
VT5	-	-	1·5	1kc/s

b) Detector The detector is connected to the Source via a 75 ohm attenuator, nominally 120dB. The Gain control should be at maximum, and a 20% reading obtained on the null meter by adjusting the source input level.

Measuring Point	Voltage
VT11 Collector	0·12
MR9 Cathode	0·04
VT13 Collector	1·0
VT14 Emitter	1·0

COMPONENT LIST

Ref.	Value			Manufacturer's Type No.
R1	6·8kΩ	0·1W	±10%	Carbon LX Radio Resistor
R2	1kΩ	0·1W	±10%	Carbon LX Radio Resistor
R3	1kΩ	0·1W	±10%	Carbon LX Radio Resistor
R4	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R5	680Ω	0·1W	±10%	Carbon LX Radio Resistor
R6	15kΩ	0·1W	±10%	Carbon LX Radio Resistor
R7	1·8kΩ	0·1W	±10%	Carbon LX Radio Resistor
R8	220Ω	0·1W	±10%	Carbon LX Radio Resistor
R9	820Ω	0·1W	±10%	Carbon LX Radio Resistor
R10	1kΩ	0·1W	±10%	Carbon LX Radio Resistor
R11	1kΩ	0·1W	±10%	Carbon LX Radio Resistor
R12	1·5kΩ	0·1W	±10%	Carbon LX Radio Resistor
R13	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R14	1·5kΩ	0·1W	±10%	Carbon LX Radio Resistor
R15	33Ω	0·1W	±10%	Carbon LX Radio Resistor
R16	2·2kΩ	0·1W	±10%	Carbon LX Radio Resistor
R17	33Ω	0·1W	±10%	Carbon LX Radio Resistor
R18 (100kc/s)	15Ω	0·1W	±10%	Carbon LX Radio Resistor

Ref.	Value			Manufacturer's Type No.
R19	Not Fitted			
R20	8·2kΩ	0·125W	±1%	Metal Film Alma
R21	100Ω	0·125W	-0 +1%	Metal Film Alma
R22	1kΩ	0·125W	±0·1%	Metal Film Alma
R23	3·9kΩ	0·1W	±10%	Carbon LX Radio Resistor
R24	A. I. C.	0·125W	±2%	H. S. Metal Film MA Alma
R25	100Ω	0·1W	±10%	Carbon LX Radio Resistor
R26	Not Fitted			
R27	2·7kΩ	0·1W	±10%	Carbon LX Radio Resistor
R28	15kΩ	0·1W	±10%	Carbon LX Radio Resistor
R29	4·7kΩ	0·1W	±10%	Carbon LX Radio Resistor
R30	15kΩ	0·1W	±10%	Carbon LX Radio Resistor
R31	47kΩ	0·1W	±10%	Carbon LX Radio Resistor
R32	47kΩ	0·1W	±10%	Carbon LX Radio Resistor
R33	Not Fitted			
R34	Not Fitted			
R35	3·3kΩ	0·1W	±10%	Carbon LX Radio Resistor
R36	12kΩ	0·1W	±10%	Carbon LX Radio Resistor
R37	18kΩ	0·1W	±10%	Carbon LX Radio Resistor
R38	82kΩ	0·1W	±10%	Carbon LX Radio Resistor
R39	3·3kΩ	0·1W	±10%	Carbon LX Radio Resistor
R40	390Ω	0·1W	±10%	Carbon LX Radio Resistor
R41	8·2kΩ	0·1W	±10%	Carbon LX Radio Resistor
R42	3·9kΩ	0·1W	±10%	Carbon LX Radio Resistor
R43	3·3kΩ	0·1W	±10%	Carbon LX Radio Resistor
R44	390Ω	0·1W	±10%	Carbon LX Radio Resistor
R45	8·2kΩ	0·1W	±10%	Carbon LX Radio Resistor
R46	3·9kΩ	0·1W	±10%	Carbon LX Radio Resistor
R47	Not Fitted			
R48	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R49	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R50	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R51	68kΩ	0·1W	±10%	Carbon LX Radio Resistor
R52	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R53	2·2kΩ	0·1W	±10%	Carbon LX Radio Resistor
R54	820Ω	0·1W	±10%	Carbon LX Radio Resistor
R55	270Ω	0·1W	±10%	Carbon LX Radio Resistor
R56	100Ω	0·1W	±10%	Carbon LX Radio Resistor
R57	100Ω	0·1W	±10%	Carbon LX Radio Resistor
R58	A. I. C.	0·25W	±10%	Carbon Type 16 Erie
R59	2·7kΩ	0·1W	±10%	Carbon LX Radio Resistor
R60	10kΩ	0·1W	±10%	Carbon LX Radio Resistor
R61	27kΩ	0·25W	±10%	Carbon Type 16 Erie
R62	4·7kΩ	0·25W	±10%	Carbon Type 16 Erie
C1 (100kc/s)	1500pF	350V	±2%	Silver Mica 1106S Lemco
C1 (1Mc/s)	150pF	350V	±2%	Silver Mica 1106S Lemco

Ref.	Value			Manufacturer's Type No.
C2	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C3 (100kc/s)	0·033μF	125V	±10%	Tropifoil M Wima Waycom
C3 (1Mc/s)	0·01μF	300V	±20%	700/A217 Dubilier
C4 (100kc/s)	500pF	350V	±2%	Silver Mica 1106S Lemco
C4 (1Mc/s)	40pF	350V	±5%	Silver Mica 1106S Lemco
C5	0·01μF	300V	±20%	700/A217 Dubilier
C6 (100kc/s)	1000pF	350V	±2%	Silver Mica 1106S Lemco
C6 (1Mc/s)	200pF	350V	±2%	Silver Mica 1106S Lemco
C7	0·01μF	300V	±20%	700/A217 Dubilier
C8	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C9	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C10	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C11 (100kc/s)	0·047μF	125V	±20%	Tropifoil M Wima Waycom
C12	Not Fitted			
C13	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C14	1μF	50V	±20%	CE 68DD/W T. C. C.
C15	0·01μF	300V	±20%	700/A217 Dubilier
C16	30μF	12V	±20%	CE6 Type H T. C. C.
C17	20pF	350V	±5%	Silver Mica SMP101 T. C. C.
C18	65pF			582 Stratton
C19	Not Fitted			
C20	2-9pF			C32-01 Wingrove & Rogers
C21	95pF		±2%	C12E Johnson & Matthey
C22	2-9pF			C32-01 Wingrove & Rogers
C23	998pF		+0 -0·5%	C12E Johnson & Matthey
C24	A. I. C.		±5%	Silver Mica 1106S Lemco
C25	65pF			582 Stratton
C26	0·01μF	300V	±20%	700/A217 Dubilier
C27 (100kc/s)	1000pF	350V	±2%	Silver Mica 1106S Lemco
C27 (1Mc/s)	200pF	350V	±2%	Silver Mica 1106S Lemco
C28 (100kc/s)	1000pF	350V	±2%	Silver Mica 1106S Lemco
C28 (1Mc/s)	200pF	350V	±2%	Silver Mica 1106S Lemco
C29	0·01μF	300V	±20%	700/A217 Dubilier
C30	6·4μF	25V	±20%	C426AE Mullard
C31 (100kc/s)	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C31 (1Mc/s)	0·01μF	300V	±20%	700/A217 Dubilier
C32	0·01μF	300V	±20%	700/A217 Dubilier
C33	0·01μF	300V	±20%	700/A217 Dubilier
C34	0·01μF	300V	±20%	700/A217 Dubilier
C35	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C36	0·01μF	300V	±20%	700/A217 Dubilier
C37	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C38	6·4μF	25V	±20%	C426AE Mullard
C39	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C40	0·1μF	125V	±20%	Tropifoil M Wima Waycom
C41	0·01μF	300V	±20%	700/A217 Dubilier
C42	0·1μF	125V	±20%	Tropifoil M Wima Waycom

Ref.	Value			Manufacturer's Type No.
C43	6·4μF	25V	±20%	C426AE Mullard
C44	0·01μF	300V	±20%	700/A217 Dubilier
C45	6·4μF	25V	±20%	C426AE Mullard
C46	6·4μF	25V	±20%	C426AE Mullard
C47	6·4μF	25V	±20%	C426AE Mullard
C48	6·4μF	25V	±20%	C426AE Mullard
C49	10pF	350V	±10%	Ceramic N750A Erie
C50	10pF	350V	±10%	Ceramic N750A Erie
C51	100pF	350V	±5%	Silver Mica 1106S Lemco
C52	100pF	350V	±5%	Silver Mica 1106S Lemco
C53	4·7pF	350V	±5%	Silver Mica 1106R Lemco
C54	100pF	350V	±5%	Silver Mica 1106S Lemco
C55	0·22μF	125V	±10%	Tropifoil M Wima Waycom
MR1	HS1010			Hughes
MR2	HS1010			Hughes
MR3	Not Fitted			
MR4	Not Fitted			
MR5	OA91			Mullard
MR6	OA91			Mullard
MR7	OA91			Mullard
MR8	OA91			Mullard
MR9	OA70			Mullard
MR10	HS1010			Hughes
MR11	HS1010			Hughes
MR12	OA5			Mullard
MR13	OA5			Mullard
MR14	OA5			Mullard
MR15	OA70			Mullard
VT1	OC170			Mullard
VT2	OC170			Mullard
VT3	OC170			Mullard
VT4	OC75			Mullard
VT5	OC75			Mullard
VT6	OC170			Mullard
VT7	OC170			Mullard
VT8	OC170			Mullard
VT9	OC170			Mullard
VT10	OC170			Mullard
VT11	OC170			Mullard
VT12	OC170			Mullard
VT13	OC71			Mullard
VT14	OC71			Mullard
T1/1 (100kc/s)	To drg D12103			Wayne Kerr
T1/2 (1Mc/s)	To drg D12106			Wayne Kerr

T2		
T3/1 (100kc/s)	To drg D12128	Wayne Kerr
T3/2 (1Mc/s)	To drg D12130	Wayne Kerr
T4/1 (100kc/s)	To drg D12129	Wayne Kerr
T4/2 (1Mc/s)	To drg D12131	Wayne Kerr
L1/1 (100kc/s)	To drg D12104	Wayne Kerr
L1/2 (1Mc/s)	To drg D12107	Wayne Kerr
RV1	1kΩ	MP Dealer Plessey
RV2	500Ω	Linear Carbon 'U' Morganite
RV3	10kΩ	MP Dealer Plessey
RV4	1kΩ	Type 37 AB Metals
RV5	500Ω	Type 37 AB Metals
RV6	500Ω	Linear Carbon 'U' Morganite

POWER SUPPLY UNIT

The power supply circuit used in the B201 is a standard Wayne Kerr item (PS109), and the circuit reference numbers commence from '1'. The components, shown in Fig. 3, should not be confused with the components of the main circuit, Fig. 10.

R1	470Ω	C1	64μF
R2	1·2kΩ	C2	64μF
R3	18kΩ	C3	64μF
R4	1·2kΩ	C4	64μF
R5	2·2kΩ		
R6	39kΩ	VT1	OC205
R7	22kΩ	VT2	OC305/2
R8	56Ω	VT3	OC305/2
		VT4	OC201
RV1	4·7kΩ		
		MR1	OAZ201

APPENDIX I

MEASUREMENT CONDITIONS

The r. f. voltage applied to the Unknown, at balance, is equal to the source voltage on LOW (BNC) and is (source voltage)/10 on HIGH. The internal source gives approx. 2V peak-to-peak. When an external source and detector are used the level and sensitivity required for a discrimination of 1 minor division can be deduced from the relationships:

$$\frac{V_{in}}{V_{out}} \text{ at 1Mc/s should exceed } \frac{10^6}{R} \quad \text{and}$$

$\frac{V_{in}}{V_{out}}$ at 100kc/s should exceed $\frac{2 \times 10^7}{R}$

where R is the range multiplying factor. Recommended source levels are given on page 8.

On the block terminals, or when the BNC connectors are in use, a direct current not exceeding 100 mA may be allowed to flow into the Bridge for periods of up to half an hour.

APPENDIX II

LOW ADMITTANCE ADAPTOR LY201

This unit, which consists essentially of two auto-transformers, is designed for operation at 1Mc/s. In conjunction with the LOW x 1 range of the Bridge it permits measurements to be made from 0 to 1pF and from 0 to 10μMho. Accuracy is better than ±0·5% ± 1 minor division from 0·1pF to 1pF and from 1μMho to 10μMho. Discrimination is to better than 0·0001pF and 0·001μMho.

Values exceeding 1pF or 10μMho will normally be measured on the Bridge itself but, if it is desired to measure up to 10pF or 100μMho whilst the LY201 Adaptor remains connected, the Bridge may be set to the x 10 range with little or no loss of accuracy.

The Adaptor is provided with two short leads terminated in BNC connectors which are fitted to the LOW sockets of the Bridge. Assuming that the Bridge has already been trimmed, on the x 1 range at 1Mc/s, re-trimming will not usually be necessary when the Adaptor is connected. The short low-capacity leads are used for connecting the Unknown to the Adaptor. If it is desired to make a measurement at some distance from the Bridge, the extension leads provided should be used between the Bridge and Adaptor. The longer low-capacity clip leads are not suitable for use from the Adaptor to the Unknown. This is because the shunt loading would be too high: 10pF from E to Neutral, or from I to Neutral, disturbs the balance point by +0·05%.

APPENDIX III

MEASUREMENT LEADS

The standard measurement leads have BNC connectors for the LOW sockets of the Bridge and crocodile clips for connection to the Unknown. For normal (two-terminal) measurements (on the LOW ranges) the component under test is connected between the two red leads. The green lead from each cable can be clipped back on to the metal sleeve (between the moulded

sections) of its own cable. (Cross-connection is not advised: the E and I Neutrals are linked internally and further connections would constitute a loop).

For three-terminal measurements the two red leads provide the connections to the component under test and the third (Neutral) 'terminal' is provided by the green lead of the I cable.

When extreme accuracy is essential the impedance of the leads can be taken into account. Typical values of the total series resistance and inductance for the two leads are 0·14 ohm and 1·5 microhenrys. Individual figures can be obtained by comparing the measured value of a component connected (a) directly to the LOW sockets, and (b) at the end of the leads.

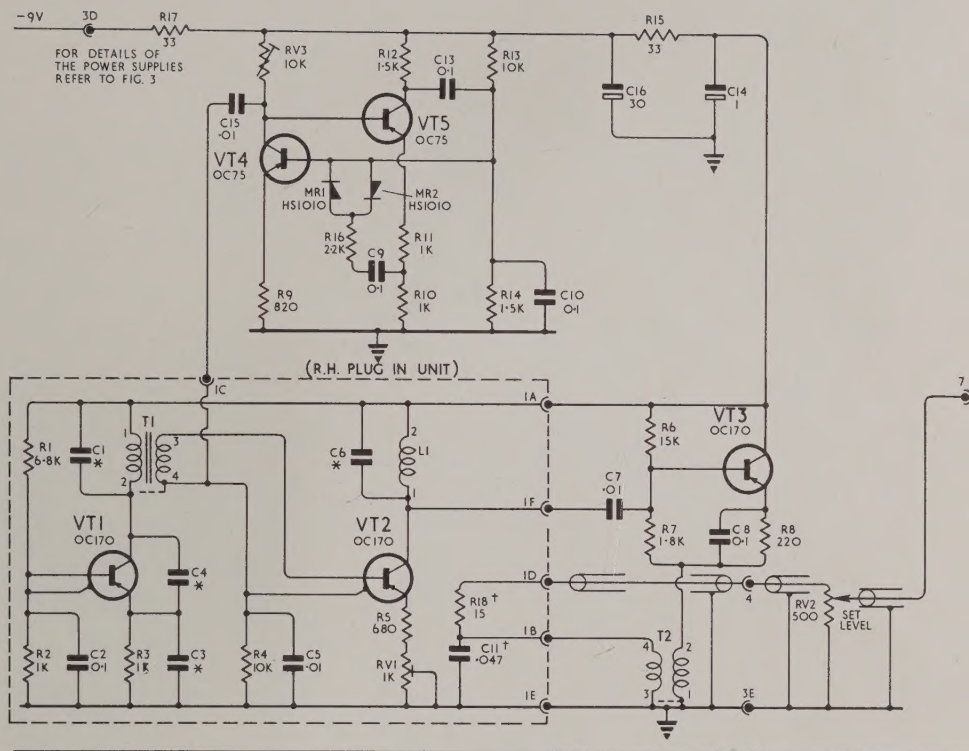
The Low Capacitance Clip leads provide connections for the measurement of the smaller capacitances with only a minimum length of the lead inner unscreened. As with the standard measurement leads, the green (Neutral) lead of each should be clipped back on to the metal sleeve of its own cable. When a third terminal is required, use the green lead of the I cable.

Since the Bridge provides a resolution of up to five significant figures it is important to bear in mind that long measurement leads may cause alteration in the apparent values(s) measured, and all leads should be kept as short as possible, particularly at the higher frequencies.

TABLE OF MEASUREMENT RANGES

C		Terminal	Range	G	
Minor Division	4-figure coverage	Connection	Multiplier	Minor Division	4-figure coverage
0·0001pF	0·1 - 1·0pF*	LY201/÷100	x1	0·001μMho	1 - 10μMho* (0·1 - 1·0MΩ)
0·001pF	1 - 10pF	÷100 (BNC)	x1	0·01μMho	10 - 100μMho (10 - 100kΩ)
0·01pF	10 - 100pF		x10	0·1μMho	100 - 1000μMho (1 - 10kΩ)
0·1pF	100 - 1000pF*		x100	1·0μMho	1000 - 10 000μMho* (100 - 1000Ω)
0·1pF	100 - 1000pF	HIGH (BLOCK)	x1	1·0μMho	1000 - 10 000μMho (100 - 1000Ω)
1·0pF	1000 - 10 000pF		x10	10μMho	0·01 - 0·1Mho (10 - 100Ω)
10pF	0·01 - 0·1μF*		x100	100μMho	0·1 - 1·0Mho* (1 - 10Ω)

4-figure coverage gives accuracy of ±0·1% ± 1 minor division
except where marked * which gives ±0·5% ± 1 minor division



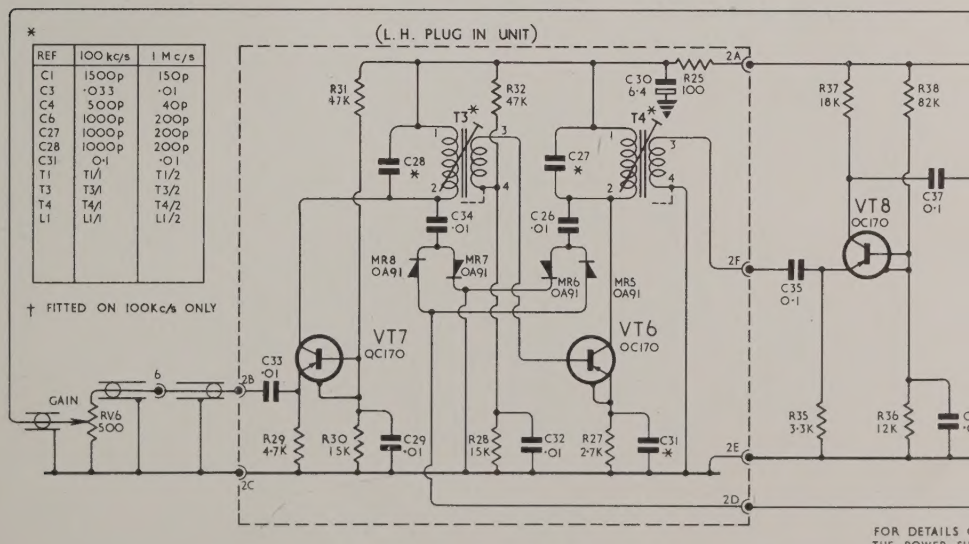
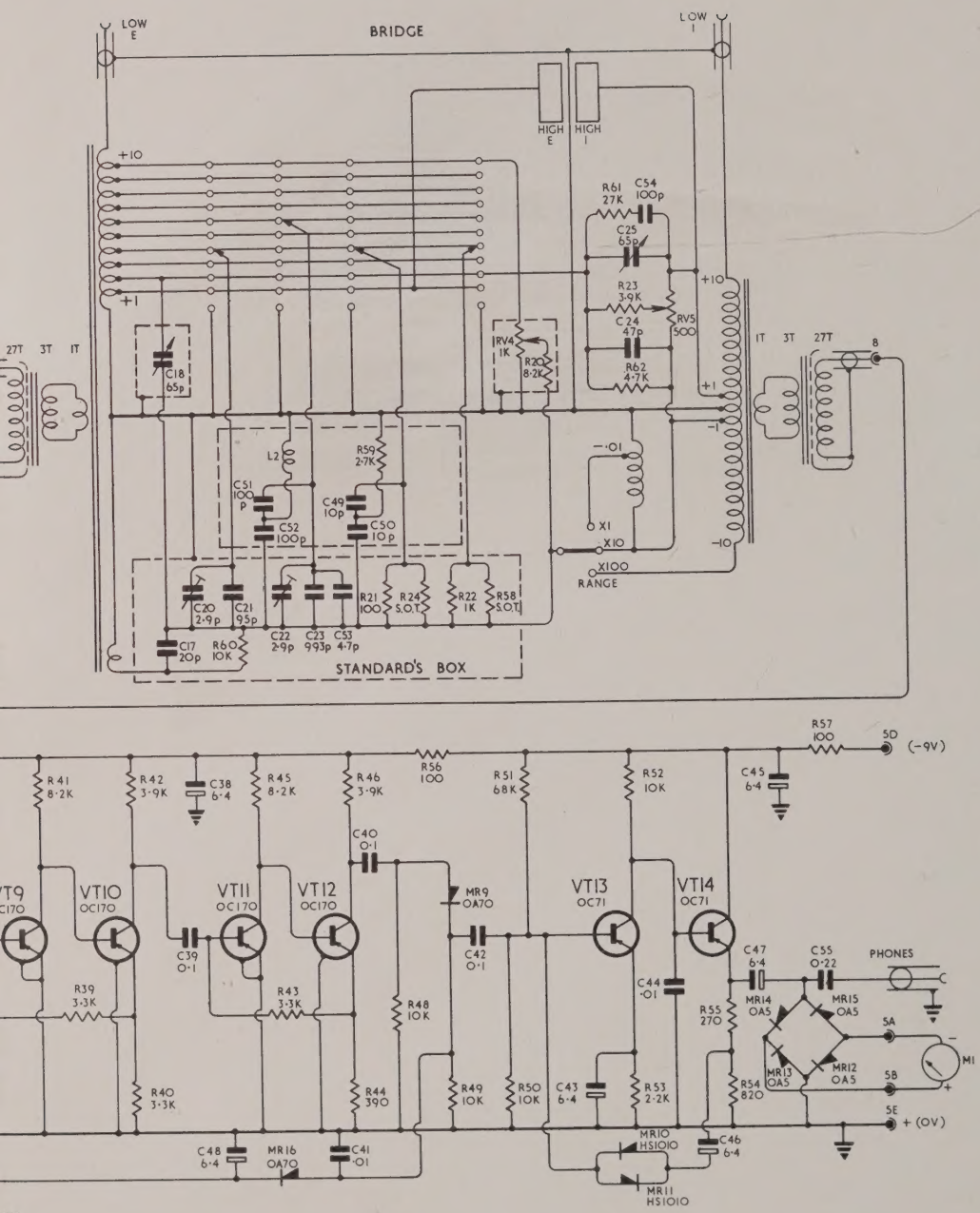


FIG. 10 CIRCUIT DIAGR


LOW E
BRIDGE
LOW I
HIGH E
HIGH I
+10
+1
R61 27K
C54 100p
C25 65p
R23 3·9K
C24 47p
R62 4·7K
RV5 500
RV4 1K
R20 8·2K
C18 65p
L2
R59 2·7K
C51 100 p
C49 10p
C52 100p
C50 10p
·01
X1
X10
X100
RANGE
-10
-1
27T 3T 1T
1T 3T 27T 8
C20 2·9p
C21 9·5p
C22 2·9p
C23 993p
C53 4·7p
C17 20p
R60 10K
R21 100
R24 S.O.T.
R22 1K
R58 S.O.T.
STANDARD'S BOX

R57 100
5D
(-9V)
R41 8·2K
R42 3·9K
C38 6·4
R45 8·2K
R46 3·9K
R56 100
R51 68K
R52 10K
C45 6·4
C40 ·01
VT9 OC170
VT10 OC170
VT11 OC170
VT12 OC170
MR9 OA70
VT13 OC71
VT14 OC71
C39 ·01
C42 ·01
C47 6·4
C55 ·022
PHONES
C44 ·01
R39 3·3K
R43 3·3K
R48 10K
R55 270
MR14 OA5
MR15 OA5
MR13 OA5
MR12 OA5
5A
5B
5E
M1
+ (OV)
R40 3·3K
R44 390
R49 10K
R50 10K
C43 6·4
R53 2·2K
R54 820
C48 6·4
MR16 OA70
C41 ·01
MR10 HS1010
MR11 HS1010
C46 6·4

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TELEPHONE : MALden 2202
TELEGRAPH : WAYNKERR, NEW MALDEN

THE WAYNE KERR LABORATORIES LTD.
SYCAMORE GROVE, NEW MALDEN, SURREY

TELEPHONE : (201) 746-2438
TELEGRAPH : WAYNKERR, MONTCLAIR, NEW JERSEY

WAYNE KERR CORPORATION
22 FRINK STREET, MONTCLAIR
NEW JERSEY, 07042 U.S.A.

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